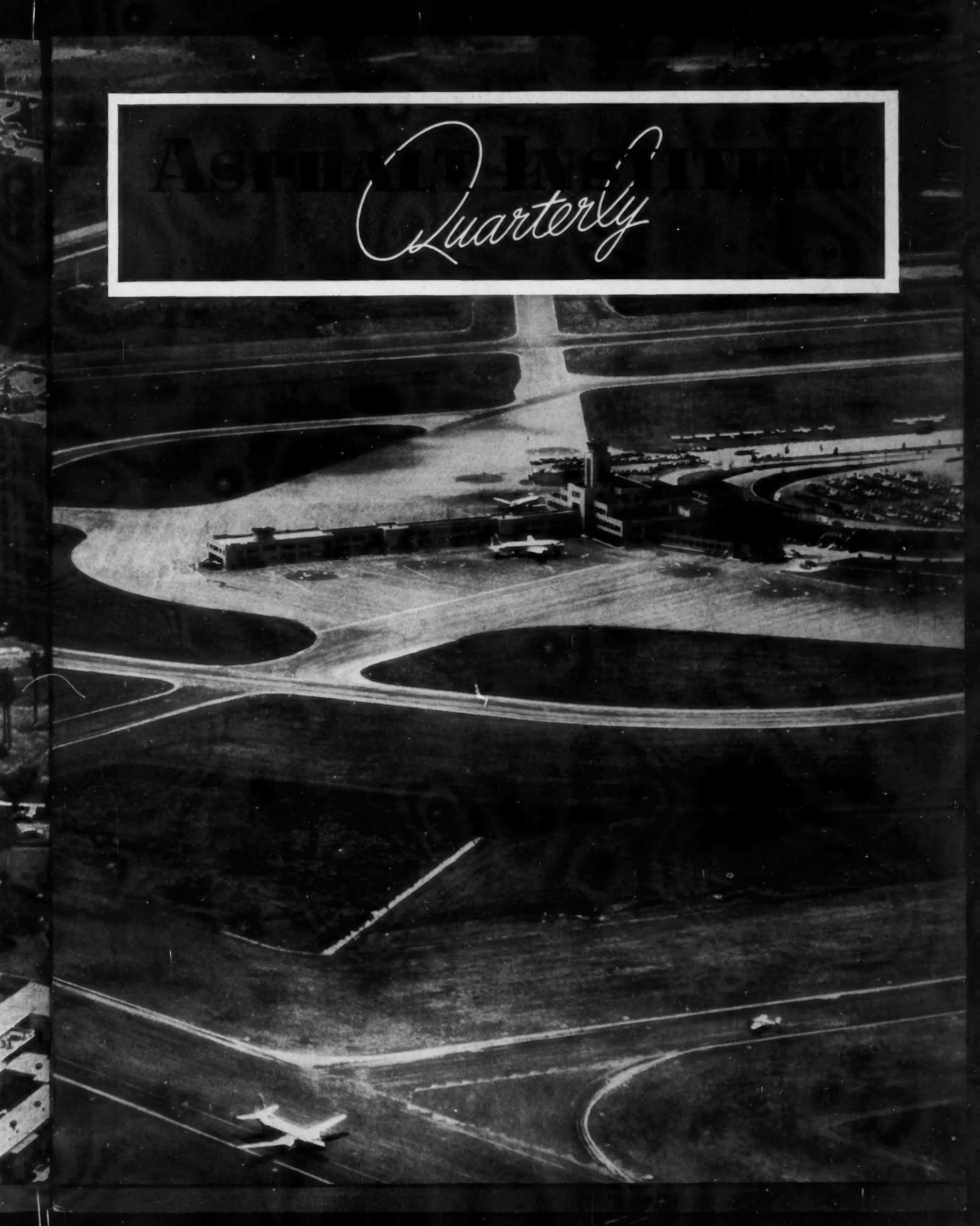
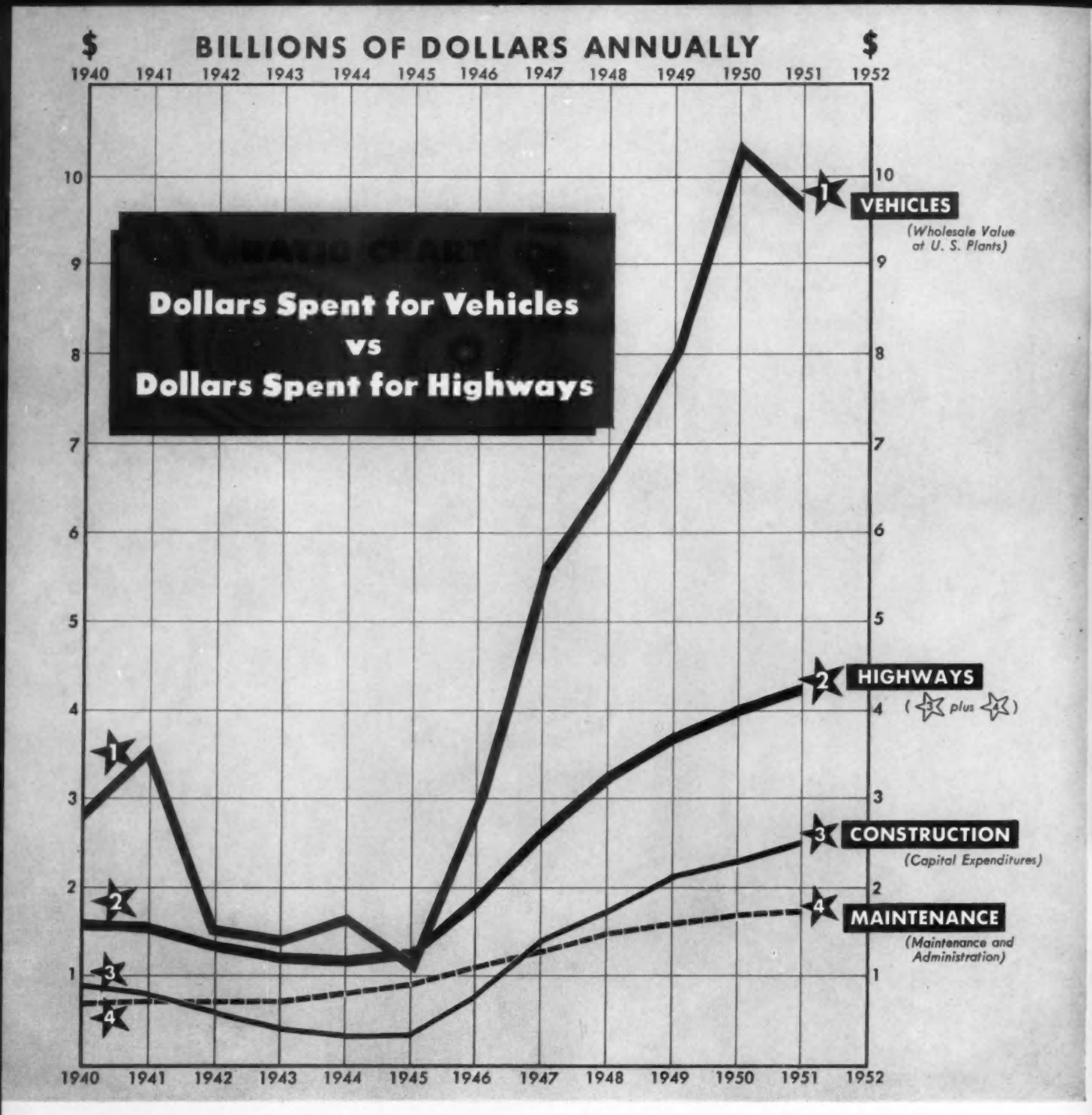
Asphalt Institute Quarterly




$ BILLIONS OF DOLLARS ANNUALLY $
1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952
Dollars Spent for Vehicles
vs
Dollars Spent for Highways
1 VEHICLES
(Wholesale Value at U. S. Plants)
2 HIGHWAYS
(plus)
3 CONSTRUCTION
(Capital Expenditures)
4 MAINTENANCE
(Maintenance and Administration)
1 2 3 4 5 6 7 8 9 10

The above Ratio Chart with its mounting blue line reflects the runaway race by motor vehicle builders in the years from 1945 to 1950. For 1951 this line turns down, and the preliminary figures for 1952 would carry it still lower with the year's total at nine billion dollars.

Highway expenditures, all in the lower half of the chart, reached four billion dollars for 1950 and continued sharply upward in 1951. Figures are not yet available for 1952 but it was a year in which paving mileage gains continued high.

The annual *Ratio of Highway to Vehicle* expenditures is still below that of 1940, but this lower highway proportion does not indicate neglect. The fact is that sound building of a highway foundation, correct choice of surfacing, and intelligent maintenance produce roads that *improve* year by year as they carry increasing weight and frequency of traffic.

In recent years, with the steadily accelerating growth of asphalt mileage to nearly 90% of the paved total, much of the annual Maintenance expenditure might well have been credited to "Additions and Betterments", since the older roads have been greatly improved as they have been maintained.

SOURCES: 1 — Automobile Manufacturers Association
3 & 4 — U. S. Bureau of Public Roads

CHARTED BY THE ASPHALT INSTITUTE, JULY 1953

Quarterly

The Asphalt Institute Quarterly is published by the Asphalt Institute, a national, non-profit organization sponsored by members of the industry for the purpose of promoting interest in the use of asphaltic products.

The names of the Member Companies of the Institute, who have made possible the publication of this magazine, are listed herein on page 15.

EDITORS

Bernard E. Gray, *President of The Asphalt Institute*
Ernest M. Bristol, *Director of Public Relations*

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Articles may be freely reprinted with credit line. Correspondence should be addressed to the Asphalt Institute Quarterly, 801 Second Avenue, New York 17, N. Y.

COVERS

Featured on the covers is Friendship International Airport, at Baltimore, Maryland. Its runways, taxiways and aprons, designed to accommodate every type of aircraft, are paved entirely with asphalt. New construction methods (see page 7), principally the stress-conditioning of the earth by super-compacting, made practicable the use of an asphalt pavement but ten inches in depth.

Air Photo: Ostergaard

In the chart on page 2, the highway expenditures for construction and maintenance are those compiled by the United States Bureau of Public Roads from federal, state, local and city sources. They are presented as the Bureau's "estimates of expenditures for highway and street purposes by federal, state and local governments in continental United States."

EDITORIAL

Change — that is the word which most aptly describes the times in which we live. Procedures that were satisfactory yesterday are not so today; tomorrow they may change again. Adjustments to meet these new conditions must continually be made if full advantage is to be taken of current technological advancement. This is as true for the paving field as for any other, and in respect to the former it applies particularly to *load-support qualities* and *surface textures*.

Pavement design for both highways and airfields is related more to tire development than to any other one factor, for the manner of weight distribution is far more important than total weight alone. Engineers in charge of road maintenance in the late twenties will undoubtedly recall that damage to roadbeds increased along with weight and volume of traffic, and that this development was not given the attention it required. In fact a losing battle was being waged to keep highways in condition. As airfield paving was practically non-existent at the time, no problems in this regard had yet arisen.

The turn in the tide of engineering difficulties was brought about not so much by new developments in paving techniques as by substitution of a new *low-pressure tire* which replaced the former hard-cord type. Monuments should be erected honoring the inventor of the balloon tire, for without doubt it was this invention which made practicable the rapid and steady development of the motor vehicle of today.

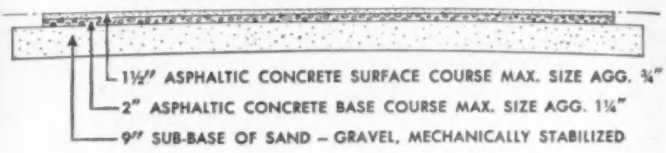
Following general adoption of the wider, softer tire, an interesting development took place. Pavements which had been on the verge of failure began to improve under maintenance alone, and with the simplification of the load distribution problem, it was found that low-cost asphalt pavements proved adequate for tens of thousands of miles of lighter roads. Built within practicable taxation limits, these asphalt pavements actually made possible the development of the motor industry, the petroleum industry, and a thousand others related to them, whose rapid growth has changed the picture of America in the past twenty-five years.

Moreover, not only had there been the benefit of this change in weight distribution behavior, but also another improvement had come about in respect to *vehicle stability* when brakes were quickly applied. Since the former cord tire had a very small contact area, brake efficiency had been low, and slippage occurred rather readily even at ordinary speeds. As evidence of the contrast in tire efficiency, the area of contact under a Ford 5-passenger sedan in 1929 was approximately 15 square inches, whereas in 1953, it has increased to approximately 35 square inches, or 2⅓ times the former area. Skid resistance is, of course, related to a number of other frictional factors, but it is evident that the greater the area of contact between tire and pavement, the greater the effective safe-stopping power for any given vehicle weight.

Thus while both motor vehicles and airplanes have become heavier as well as more numerous, in many respects it is much easier to build and maintain *pavements* today than ever before. The problems now do not so much concern weight and frictional resistance as how to provide for the additional *areas* needed for maximum mobility of millions of cars, trucks and planes.

SOME FACTORS AFFECTING AIRFIELD DESIGN

ASPHALT RUNWAY — CROSS-SECTION


1½" ASPHALTIC CONCRETE SURFACE COURSE MAX. SIZE AGG. ¾"
2" ASPHALTIC CONCRETE BASE COURSE MAX. SIZE AGG. 1¼"
9" SUB-BASE OF SAND – GRAVEL, MECHANICALLY STABILIZED

Only twelve short years ago this country was entering upon a great airfield building program for both commercial and military purposes. With gross loads even then greater than any encountered on highway pavements it became necessary to develop new methods for foundation appraisal as well as easier and more rapid procedures for design of mixtures. Today's larger, heavier planes, with changing engine types, will now again require engineering decisions involving design improvements and large construction costs.

Present-day planes may weigh as much as 400,000 pounds, as contrasted with a maximum of 65,000 pounds only twelve years ago. Both take-off and landing speeds are higher, so that runways as long as 15,000 feet may now be required, compared with only about one-third that length in 1941. Paving engineering, by lengthening and strengthening existing fields, and by employing the science of soil mechanics in new construction, is adequately and economically meeting the sudden great changes demanded by the growing aviation industry.

What is airfield paving? Fundamentally it consists of various areas of ground from which planes can take off and land — safely. By the very nature of an airplane, the various speeds at which it moves and the angle at which it leaves or lands, certain limits of paved areas are required which should be very definitely outlined. Thus there are (a) runways, traversed at both high and low rates of speed, (b) servicing and parking areas where planes are largely at rest, and (c) taxiways between the two over which movement is slow. Correct layout of these areas will have marked effect upon efficiency of movement; the surfaces also may require different treatment on the several areas to provide maximum utility. Requirements for military airfields are essentially the same as for commercial, except in respect to size of parking and service areas.

What are the important items in design? There are two in particular; one, correct appraisal of loading conditions; the other, the character of the surface texture. While in 1941 there was discussion as to needed allowance for impact, it is rather universally agreed today that the most severe condition is where the plane is at rest, namely its total weight. However, as a margin of safety it is general practice to assume that this total weight is borne by the wheels under the wings, without taking into account the nose or tail supports. Experience over the years has demonstrated that pavements designed on these assumptions are more than adequate, even in the case of such high unit loading as found with certain types of military aircraft.

What do airfield pavements cost? It is here that careful engineering is required to determine true economy. As in highways, the lowest cost usually will be secured by obtaining the major portion of load support through use of native materials such as sand, gravel, crushed stone or local selected soils, which will provide adequate foundations. However, heavy-duty airfield pavements require heavier sections than on highways, because an airplane wheel-load may be twenty times that of a truck.

PAVEMENT TYPES

There are two principal types of pavement — the rigid and the flexible. Asphalt surfaces are in the latter classification. In the rigid type, which cannot deflect very much without cracking, a certain minimum thickness is required for any given load condition. For the heaviest planes this minimum could be as much as 20 inches. In the flexible type, however, which can stand much greater deflection, the supporting value of an improved subgrade and foundation is fully utilized, and for the same given load the surface thickness can be decreased as the foundation support increases.

Improved subgrades and flexible-type bases of stone and gravel are less costly per inch of depth than pavement surfaces alone. A composite design, combining such foundations with a relatively thin but tough asphalt surface, produces a heavy-duty structure which not only is adequate for service conditions expected, but one which can be obtained usually at the least expense. Often on a single large airfield this saving can be hundred of thousands of dollars, and it is thus evident that the advantages of the flexible-type pavement should always be fully explored.

DENVER'S STAPLETON AIRFIELD

The history of this commercial airport over the past thirty years is of special interest in that it exemplifies the strides paving engineers have made in keeping up with extremely rapid developments in aircraft production and design. Because of great increases in plane sizes and weights, particularly in the past 12 years, the runways of this airport have required frequent lengthening and strengthening to meet the greater wheel load capacities and runway lengths demanded by modern aviation.

In 1948 the City of Denver and the Civil Aeronautics Administration entered into a contract to reconstruct 3,230 feet of the north end of the North-South runway — originally built in 1936 — and also to construct a new East-West runway 8,500 feet long. Following C.A.A. requirements these pavements were designed for 60,000-pound wheel loads.

Not only have these new asphalt runways performed satisfactorily, but the pavement of the entire airport through the years has given extremely good service with low maintenance costs; never once in these thirty years have operations been suspended due to pavement failures. In comparing the cost of the new asphaltic concrete construction of 1952 with that of portland cement, the figures show a saving of $600,000 in favor of asphalt.

Rubber-tired rolling compacts and smooths asphalt runways at Stapleton Airfield. *Photo: Banning*

ASPHALT RUNWAY — CROSS-SECTION

PORT COLUMBUS (OHIO) AIRPORT

A typical example of the "new look" being acquired by many commercial and military airfields is the recent (1952) construction, for the use of Navy planes, of a new 8,000-foot heavy-duty asphalt runway and a new taxiway at Port Columbus Airport, located about seven miles east of the center of Columbus, Ohio. With an eye on developments in the aircraft industry and its production of bigger and heavier planes, paving engineers selected asphalt for this project as the material best able to withstand safely these increased sizes and wheel-loads.

The runway cross-section below indicates construction materials used as well as subbase and base course thicknesses; the taxiway was similarly built except that the gravel subbase was increased to 21 inches and the waterbound macadam base to 10 inches. The pavements were designed for 60,000-pound single wheel loads. To carry these loads heavy-duty asphalt flexible type construction was chosen to secure economy with required performance. Low-cost foundation materials were readily available and modern compaction methods assured their most effective use. The pavement is now adequately serving with complete satisfaction, meeting all impact and stress demands, — and Port Columbus, one of the earliest paved airports in the United States, is keeping pace with the progress of the aviation industry.

Vibro-Tamper compacting gravel subbase for asphalt heavy-duty runways at Port Columbus.

Base paver laying loose stone for compacted macadam base.

Laying and rolling 1¾" asphalt binder course before application of 1¼" asphalt wearing course.

ASPHALT RUNWAY — CROSS-SECTION

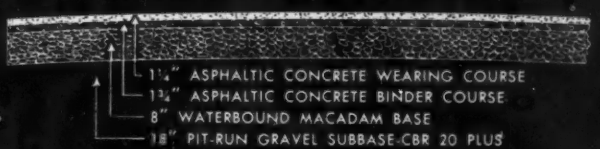

1¼" ASPHALTIC CONCRETE WEARING COURSE
1¾" ASPHALTIC CONCRETE BINDER COURSE
8" WATERBOUND MACADAM BASE
18" PIT-RUN GRAVEL SUBBASE-CBR 20 PLUS

Photo: Spence Air Photos, Los Angeles

LOS ANGELES INTERNATIONAL AIRPORT

As early as 1925, airplanes occasionally landed in a bean field southwest of Los Angeles. Three years later, a runway was constructed there — a single 2,200-foot macadam strip — but activity at the field was limited largely to private and charter flying. When in 1936 North American Aviation moved its employees into a new factory on the airport property, the City, encouraged by increasing use of the field, decided to buy the site. After having served as a delivery base for thousands of military aircraft during World War II, preparations were made to receive the commercial airlines, and, in December, 1946, regularly scheduled flights to all parts of the world were begun. The City had long since grown to surround the airfield, and in 1949 the old Municipal Airport received a new name. Today, the Los Angeles International Airport holds the rank of fourth largest commercial airport in the United States in volume of air traffic.

In this brief but remarkable story of progress and development — from bean field to world air terminal in 25 years — heavy-duty asphaltic materials have played a large and important part. Although the two original main runways, built of asphalt in 1938 and 1939, for twelve years admirably served and supported very heavy traffic with only minor maintenance, changes and developments in aircraft production and design not only necessitated extension of the runways but also required increases in the load-bearing capacity of both old and new sections. This work was accomplished during the period 1948-1951, the first extension being to 6,000 feet; the next, and most recent, to 8,500 feet.

The new section, consisting of 3 inches of heavy-duty asphalt applied over 10 inches of sand clay base stabilized with asphalt emulsion, is designed to withstand wheel loads of 120,000 pounds. As a result of this construction, the Los Angeles International Airport, another example of the trend toward longer and stronger pavement runways made necessary by increased aircraft sizes and wheel loads, is now capable of accommodating the heaviest planes.

MARCH AIR FORCE BASE RIVERSIDE, CALIFORNIA

The "Independence" on the Asphalt at Friendship. *Photo: Dent*

FRIENDSHIP INTERNATIONAL AIRPORT AT BALTIMORE

This commercial airport is one of the finest in the world. Located about nine miles outside of Baltimore, twenty-nine miles northeast of Washington, D. C. and twenty-one miles north of Annapolis, it is designed for expressway service to the entire area.

The gigantic proportions of "Friendship" are suggested in the overall illustration on the double covers of this Quarterly — 800,000 square yards of asphalt pavement on a 3,200-acre airport. The runways, taxiways and aprons, all of asphalt, appear extending in practically all directions from the Administration Building at the right. These long runways, ranging in length from 6,500 to 10,000 feet and in width from 150 to 200 feet, are all three partially in view.

Construction work at Friendship, carried on from 1947 to its opening on June 24, 1950, involved the excavation of 7,000,000 cubic yards and the placing of 400,000 tons of asphalt plant mixture. The pavement was built to withstand a gross load of 200,000 pounds.

NEW ENGINEERING CONSTRUCTION METHODS

This was one of the first commercial airports upon which a 200-ton heavy roller was used in super-compacting the subgrade. This compaction extended to a depth of five feet and secured a strong uniformity that made unnecessary any variation in pavement thickness to meet changing conditions.

Above the subgrade foundation and subbase the runways were paved with ten inches of asphaltic mixtures in four layers, designed with a 7″ sand asphalt base in two 3½″ courses, topped by 3″ of asphaltic concrete in two equal 1½″ binding and wearing courses.

Sufficient sand was salvaged and stockpiled in the excavation work so that there was enough available not only for subbase but also to construct the entire 7″ of sand asphalt base courses. The asphalt mix was produced in three mixing plants erected on the site near the sand stockpiles. The coarse aggregate used in the binder and wearing courses was crushed stone. This 10″ asphalt pavement cost about $3.00 per square yard. Without super-compaction it would have required a 17″ thickness, plus additional subbase.

It is estimated that by super-compacting the soil and using local materials found at the site that the engineers *saved more than $3,000,000* in construction costs compared with older conventional construction methods.

1 Spreading and compacting sub-base material.

2 Compacting crushed stone base course with vibrating compactor.

3 Applying asphalt prime coat to crushed stone base course.

ALTUS AIR FORCE BASE OKLAHOMA

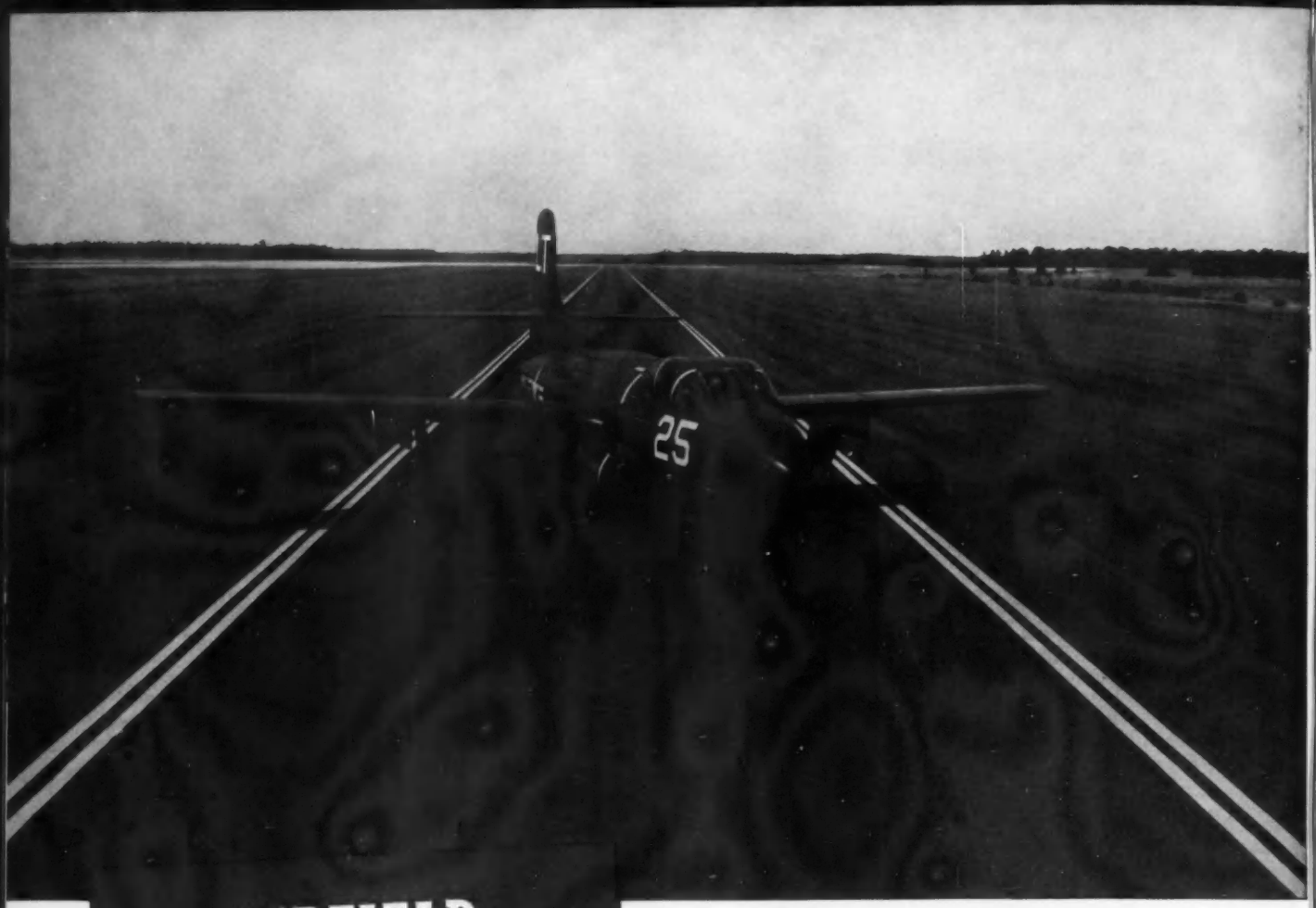
4 Placing and rolling 2½″ asphalt binder course.

5 Cutting density specimen of asphalt pavement by use of power saw.

Photos: Wallace

Originally constructed early in World War II, the Altus Air Force Base is another of the many military airfields which have required reconstruction because of recent increased aircraft sizes and weights. The new heavy-duty main runway, extended to 10,800 feet and designed for wheel loads up to 100,000 pounds, is composed of three subbase courses, a base course, and hot-mix asphalt binder and surface courses of 2½ inches and 1½ inches, respectively.

The lowest subbase (No. 1) consists of 3 to 11 inches of upgraded subgrade soil (a soil of higher bearing capacity than that in place). No. 2 subbase is composed of 6 inches of dune sand, while No. 3 is a 5-inch thickness of the former salvaged asphalt pavement to which is added and blended approximately 10 per cent dune sand. The crushed stone base course is 6 inches thick and is compacted to 100 per cent modified A.A.S.H.O. density, as are all subbase courses. All areas of this airfield are paved with asphalt and those to be subjected to particularly heavy-duty usage are similarly designed for the 100,000-pound wheel load.



AIRFIELD PAVEMENTS for JET AIRCRAFT

An F3D Skynight jet poised for flight, awaiting its turn in the flight pattern from an asphalt runway at the giant Marine Corps Air Station, Cherry Point, North Carolina.
Photo: U. S. Marine Corps

The jet airplane, once an unbelievable creation of science-fiction, has become a reality. Public reaction to the distinctive roar of a jet engine now stems more from curiosity than awe. The jet today is regarded as one of the inevitable next steps in aviation progress; its existence is taken for granted. At present jet aircraft are built almost exclusively for military use, although recently a few commercial jet airliners have been placed in service abroad. It is more than likely, of course, that some day every large commercial airline will boast a fleet of jets flying the inter- and transcontinental routes.

Through experience gained at military airfields, the paving engineer has already discovered that certain characteristics of jet aircraft have created new conditions and problems not previously encountered with conventional aircraft.

These new conditions, potentially damaging to pavements, are produced by:

1. Extreme heat and high-velocity blasts from jet turbine exhausts
2. Spillage of relatively large quantities of jet fuel
3. Extremely high tire-inflation pressures

EXHAUST HEAT AND BLAST

In studying heat and high-velocity blasts from jet turbines, the paving engineer is concerned only with conditions at the pavement surface level. These conditions in turn are dependent upon many factors of plane design and operational conditions, such as:

a. Heat and blast velocity conditions at the jet turbine exhaust orifice
b. Height of exhaust orifice above the pavement surface
c. Angle of inclination of the axis of the jet turbine with the pavement surface
d. Prevailing air temperature, and wind direction and velocity
e. Length of time during which the heat and blast are applied on a given pavement area

The U. S. Corps of Engineers, in collaboration with Air Force Engineers, has conducted one of the most thorough studies to date on the effects of jet turbine heat and blast. At several Air Force Bases time-motion studies were made dealing with the movements and operational characteristics of commonly used jet planes. Upon completion of the studies the planes were tested upon specially prepared sections of conventional pavements in which were installed instruments to measure temperature and blast velocity. Temperatures and velocities were determined at the pavement surface level and in the path of the jet turbine exhaust. Temperature measurements were also made at several depths in the pavements. These tests established two important facts:

A. Conventional pavement surfaces were not damaged unless they reached a temperature in excess of 300°F.

B. Under normal operating conditions of planes used in these tests, pavement temperatures did not exceed 300°F.

On the basis of these studies, it may be concluded that conventional pavements are adequate for normal operation of current Air Force jet aircraft. In fact, except under rare abnormal conditions, the estimates of paving engineers indicate that in no case have damaged areas approached *even one percent* of the total paved area; the damage itself, for all practical purposes, has been negligible.

FUEL SPILLAGE

A second source of potential damage to pavements is fuel spillage, which has been of some consequence at a few military installations. This can generally be eliminated by careful handling, although in a few of the early jet planes leakage of fuel occurred through overflow lines during taxiing operations. In some instances, however, fuel tanks are filled to capacity and the planes are parked in the sun, with the result that the fuel expands and overflows onto the pavement. Occasionally, incomplete combustion in starting or stopping the jet turbine may cause a small amount of fuel to spray on the pavement, but the quantity is usually negligible. Sometimes several gallons of fuel in supply lines may drip slowly on the pavement when the plane is stopped. Although fuel spillage *may* be damaging to pavements, that possibility has been largely overcome by improvements in plane design and through the elimination of carelessness in refueling operations.

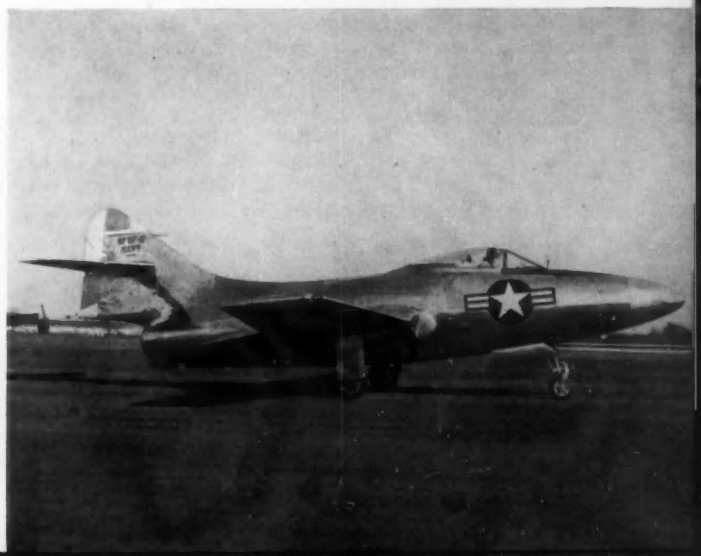
HIGH TIRE-INFLATION PRESSURE

High tire-inflation pressures constitute another source of potential damage to airfield pavements. Tires inflated to pressures up to 240 pounds per square inch are used now by jet aircraft and there are possibilities of further pressure increases. These high-pressure tires serve to concentrate the stresses imposed on a pavement surface, but adequate asphaltic pavements can be easily designed and built to withstand the greater strain. Experimental work by the Corps of Engineers has led the way in this field and has indicated the requirements for such pavements. Nearly all new asphaltic pavements at military installations are now being designed and built to withstand these higher pressures.

Experience over the past several years at military airfields as well as a considerable amount of experimental work have indicated that the most suitable asphaltic pavement for jet airfields is a densely-graded mixture with a relatively smooth-textured surface. Suitably-graded aggregates with the proper asphalt content are prerequisites for such pavements. Both the Corps of Engineers and the Navy have aggregate gradation specifications and methods for determining the asphalt content of the mix to insure satisfactory performance. Good construction methods are then necessary to produce satisfactory finished results. Rubber-tired rolling equipment has been very successfully used during rolling operations while the pavement is still hot. These rollers produce a dense-textured and impermeable pavement surface which most satisfactorily resists the effects of heat and blast, damage by spilled fuel, and the additional stresses caused by high tire-pressures.

END

Republic Aircraft's Air Force jet fighter. Its horizontally-mounted turbine minimizes possibility of damage to conventional airfield pavements.



The Grumman F9F Navy jet fighter on the compressed, smooth-textured, impermeable asphaltic test pavement at Bethpage, Long Island.

ASPHALT OVERLAYS Strengthen AIRFIELD PAVEMENTS

By John M. Griffith
Engineer of Research

Since the beginning of World War II there has been a tremendous increase in the size and gross weight of military aircraft. Planes which only a few years ago the Air Force classified as "very heavy bombers" are now lightweights by comparison. For example, B-17's and B-24's were known as "very heavy bombers" and had a maximum gross weight of approximately 60,000 pounds. The gross weight of the modern, fully loaded B-36 is nearly seven times as much — approximately 400,000 pounds. Many of our new fighter planes also are much heavier than those manufactured before and during World War II.

In commercial aviation the trend toward bigger and heavier aircraft is also apparent. The DC-3's which for many years served the airlines so well are now being replaced on all but some feeder lines by Convairs, DC-6's, Constellations and Stratocruisers. Some of these planes have gross loads up to approximately 140,000 pounds.

Because few airfields were originally constructed to bear these increased loads, the paving engineer has been confronted with the problem of *strengthening* airfield pavements in some way without having to rebuild them entirely — the latter task made impossible, of course, by completely prohibitive costs.

OVERLAYS ON FLEXIBLE-TYPE PAVEMENTS

Various agencies concerned with pavement construction anticipated many years ago the eventual need for new heavy-duty airfield pavements. They recognized that, in regard to flexible-type pavements, existing design procedures were adequate to determine the additional thicknesses of flexible-type *overlay* construction required to support any given wheel load. One of these agencies was the Corps of Engineers which for this purpose has continued to use its standard California Bearing Ratio (CBR) design method.

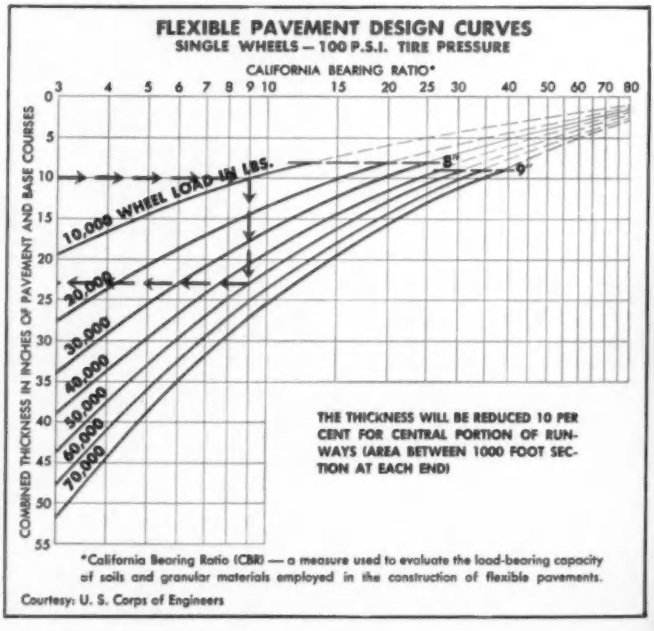
This method is described in graphic form in Figure 1, which shows the CBR design curves for single wheel loads where tire pressures are 100 pounds per square inch (p.s.i.) or less. To illustrate the use of the chart, let us assume that the total thickness of base and asphalt wearing surface of an airfield pavement is 10 inches, and that this thickness is adequate for 10,000-pound single wheel loads. We wish to increase the load-bearing capacity of this pavement to the point at which it will adequately support a 50,000-pound single wheel load. Noting on the chart that the 10,000-pound wheel-load curve crosses the 10-inch-depth intercept at a CBR of 9, we assign this CBR value to the subgrade.

Referring now to the 50,000-pound wheel-load curve we see that the total depth of base and pavement required over this same subgrade (CBR=9) is 23 inches. As 10 inches of flexible pavement are already in place, an additional pavement thickness of 13 inches is needed to support the 50,000-pound wheel load. This overlay might consist of a 10-inch, high-quality granular base and a 3-inch surface of hot-mix asphaltic concrete. Other flexible-pavement design procedures are used in a similar manner to reach the same conclusions.

OVERLAYS ON EXISTING RIGID PAVEMENTS

The problem of determining required thicknesses of overlay on existing *rigid* pavements was not so easily solved. It was apparent that overlays would strengthen these pavements, but it was not known what thicknesses were needed to provide the additional strength. The Corps of Engineers went to work on this problem and initiated studies at Maxwell Field, Alabama, and MacDill Field near Tampa, Florida, both of which were paved with portland cement concrete. Overlays of various thicknesses of hot-mix asphaltic concrete and combinations of base and asphalt surfacing were applied to the cement concrete pavements, and acceler-

FIGURE 1


FLEXIBLE PAVEMENT DESIGN CURVES
SINGLE WHEELS — 100 P.S.I. TIRE PRESSURE
CALIFORNIA BEARING RATIO*
3 4 5 6 7 8 9 10 15 20 25 30 40 50 60 70 80
COMBINED THICKNESS IN INCHES OF PAVEMENT AND BASE COURSES
0 5 10 15 20 25 30 35 40 45 50 55
10,000 WHEEL LOAD IN LBS.
20,000
30,000
40,000
50,000
60,000
70,000
8"
9"
THE THICKNESS WILL BE REDUCED 10 PER CENT FOR CENTRAL PORTION OF RUNWAYS (AREA BETWEEN 1000 FOOT SECTION AT EACH END)

*California Bearing Ratio (CBR) — a measure used to evaluate the load-bearing capacity of soils and granular materials employed in the construction of flexible pavements.

Courtesy: U. S. Corps of Engineers

LOWRY AIR FORCE BASE, DENVER

ated traffiic tests were conducted with a 60,000-pound dual wheel load representing the loading of a B-29 plane.

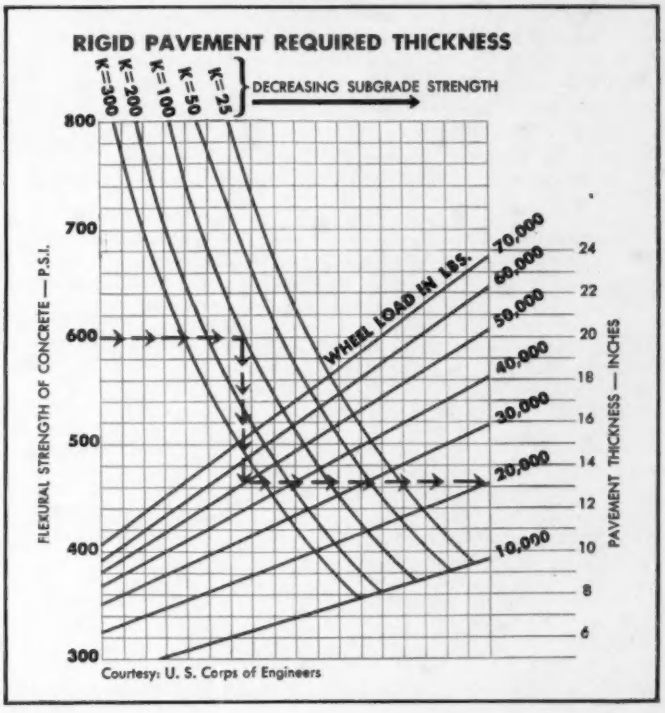
The results of these tests proved to be of considerable value in determining flexible-type overlay thickness requirements for the B-29, but additional information was needed to formulate general procedures which would be applicable not only to a wide range of wheel-loading conditions but also to rigid pavement overlays over existing rigid pavements.

At Lockbourne Air Force Base, near Columbus, Ohio, and at Sharonville, Ohio, overlay test sections of greatly expanded scope were built and tested with accelerated traffic. The extensive data accumulated from these tests have provided the Corps of Engineers with an adequate basis from which to derive design procedures. These are fully outlined in their Engineering Manual of July 1951, "Airfield Pavement Design, Rigid Pavements," Part XII, Chapter 3.

In carrying out these procedures it is first necessary to determine the thickness of portland cement concrete pavement required to support the desired wheel load. To illustrate how this is done, we will assume that the flexural strength of portland cement concrete is 600 p.s.i. and that an existing rigid pavement 8 inches thick overlays a subgrade having a modulus of subgrade reaction K of 100. We wish to increase the load-supporting capacity of this pavement to the point at which it will adequately bear a 50,000-pound wheel load.

We refer directly to Figure 2 to determine the needed thickness of rigid pavement. Entering the chart at a 600 p.s.i. flexural strength and following the indicated broken

FIGURE 2



MOISANT INTERNATIONAL AIRPORT, NEW ORLEANS

LOCKBOURNE AIR FORCE BASE, COLUMBUS, OHIO

lines and arrows we find that a rigid pavement 13 inches thick is required for the conditions specified. To discover the required thickness of *overlay* on the 8-inch existing pavement the chart in Figure 3 is employed. We enter this chart at the top at a "Full Concrete Design Thickness" of 13 inches (already determined from Figure 2) and, following the arrows, we find that a flexible pavement overlay of approximately 10 inches is needed. This overlay may consist of 7 inches of granular base and 3 inches of hot-mix asphaltic concrete.

The illustrations and examples cited in this article are for some conditions when the required thickness of new rigid pavement is less than twice that of the existing rigid pavement. However, in some other instances a new rigid pavement of more than twice the thickness of the existing pavement will be required. In these cases the chart shown in Figure 3 is subject to modification. The modified chart has been issued by the Corps of Engineers as a subsequent addendum. This latter chart is not included in this article.

FIGURE 3

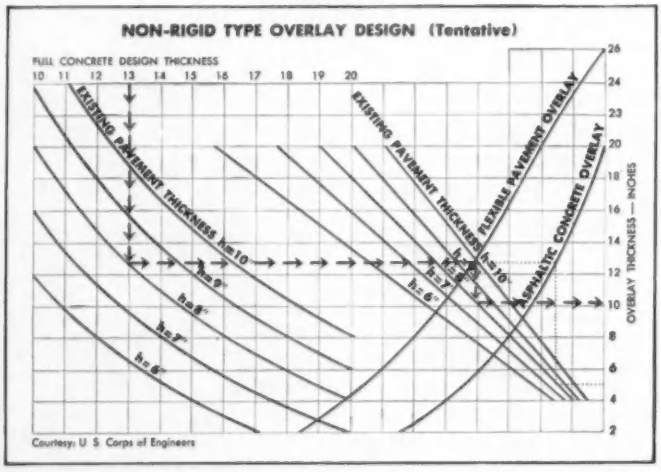

NON-RIGID TYPE OVERLAY DESIGN (Tentative)
FULL CONCRETE DESIGN THICKNESS
10 11 12 13 14 15 16 17 18 19 20
EXISTING PAVEMENT THICKNESS h=10
h=9"
h=8"
h=7"
h=6"
EXISTING PAVEMENT THICKNESS h=10
FLEXIBLE PAVEMENT OVERLAY
ASPHALTIC CONCRETE OVERLAY
OVERLAY THICKNESS — INCHES
26 24 23 20 18 16 14 12 10 8 6 4 2
Courtesy: U. S. Corps of Engineers

Figure 3 may also be used to determine the required thickness of an overlay composed entirely of hot-mix asphaltic concrete. In reading this chart the same procedure is followed except that the curve to the extreme right, labelled "Asphaltic Concrete Overlay," is used. This indicates that 5 inches of hot-mix asphaltic concrete is sufficient to increase the load-bearing capacity of the existing rigid pavement to the point where it will adequately support 50,000-pound single wheel load traffic.

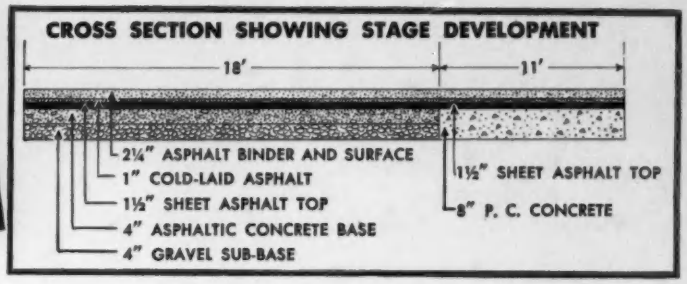
Further study of these charts, employing various sets of assumed conditions, will serve to indicate the remarkable strengthening effects of asphaltic types of resurfacing. The table below, which incorporates these types under the headings "Asphaltic Overlay" and "Flexible Pavement Overlay," also demonstrates the effects in another form. Here a portland cement concrete having a flexural strength of 600 p.s.i. and a subgrade having a modulus of subgrade reaction K of 100, were assumed, these figures representing an average condition.

These studies by the Corps of Engineers and the resulting design procedures have indicated an economical and reasonable solution to the problem of strengthening airfield pavements, and it is entirely possible that they will also help the highway engineer solve some of his problems in the rehabilitation of overloaded and worn-out highways.

STRENGTHENED WHEEL LOAD CAPACITIES

PORTLAND CEMENT CONCRETE PAVEMENT		PLUS → ASPHALTIC OVERLAY — OR — FLEXIBLE PAVEMENT OVERLAY					
		ADDED THICKNESS (INCHES)					
THICKNESS (INCHES)	WHEEL LOAD CAPACITY (LBS.)	+4"	+5"	+6"	+8"	+10"	+12"
		WHEEL LOAD CAPACITY (LBS.)					
6"	9,000	27,000	34,000	40,000	27,000	38,000	50,000
7"	13,000	34,000	40,000	47,000	31,000	42,000	54,000
8"	17,000	40,000	47,000	55,000	35,000	46,000	59,000
9"	22,000	47,000	55,000	64,000	40,000	51,000	64,000
10"	27,000	55,000	64,000	70,000+	45,000	57,000	70,000

VIRGINIA'S SEVEN PINES ROAD —After 30 Years



The true life of a pavement can only be measured in terms of service rendered and the annual cost involved. Unless the taxpaying public fully understands these two factors, it is useless to present statistics on the so-called comparative life of different pavement types. If, for example, a pavement has been widened and resurfaced it is completely misleading, unless proper notation is made regarding salvage value, to imply statistically that the original pavement had a life span covering only the period up to the time of reconstruction. It is particularly important at this time that correct figures be presented, as some agencies are giving the impression that the highway system is failing rapidly. The fact is that excellent progress is being made in providing additional required facilities. The skill and efficiency with which state highway engineering departments have been meeting changing traffic demands over the years are exemplified in the story of historic Seven Pines Road in Virginia.

GRADUAL IMPROVEMENT THROUGH MAINTENANCE

This particular project, 5.2 miles in length, was first paved in 1924. Then known as State Route 39, it was subsequently incorporated into U.S. Route 60. The road runs in an easterly direction from the city of Richmond and has always carried heavy traffic. The surface prior to 1924 had been a thin layer of untreated gravel. Additional gravel was added to provide a minimum 4-inch thickness, over which was placed a 4-inch hot-mix asphaltic concrete base and 1½ inches of sheet asphalt top. This pavement, 18 feet in width, was carrying over 2,500 vehicles daily as early as 1927, and by 1934 required widening to meet increasing demands.

It is desirable to note here that in this widening operation opportunity was taken to improve alignment, accomplished by extending the new foundation first on one side and then on the other. An 8-inch thickness of reinforced concrete was employed to match the 8-inch existing gravel and asphaltic concrete foundation, followed by placement of a 1½-inch sheet asphalt top to match the existing adjacent asphalt surface. The pavement thus became 29 feet in width and 9½ inches thick. In 1939 it was smoothed by placement of an open-graded cold-mix asphalt, averaging one inch in thickness. This surfacing improved the cross-section as to uniformity in appearance and covered the joints in the widened areas.

To provide for the very heavy volume of traffic now using this principal interstate highway, a further resurfacing was placed in 1946 consisting of 2¼ inches of hot-mix asphaltic paving. The pavement now is of three-lane capacity and has a total thickness of approximately 12 inches, with due allowance for wear. *It has been improved gradually over a period of some 30 years, as traffic demands required.* At no time has more money been invested than needed for the purpose. The pavement is stronger and smoother than at any previous time; full use has been made of all construction since the beginning; and the total cost has been less per square yard than for a totally new pavement today. It is thus apparent that true economy in highway building is represented by work of this character, and it is indeed fortunate that the very great majority of all highway routes can be improved by similar procedures.

Early spreading operations on Seven Pines Road — Original asphalt road — Present 3-lane asphalt road

ASPHALT INSTITUTE ENGINEERS

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Charles A. Mayer is Office Engineer at the Asphalt Institute's headquarters in New York, serving since his appointment in 1946 both as an administrative aid to the president and assistant to the chief engineer. With a background of over thirty years of asphalt paving experience in the field and laboratory, Mr. Mayer in his present capacity assists in promoting the over-all engineering activities of the Institute and in providing a wide range of engineering information which the Institute is called upon to supply.

Long associated with the well-known Consulting, Chemical and Paving Engineering firm of Messrs. Dow and Smith in New York City, Mr. Mayer was their Chief Inspector and later a member of the succeeding firm from 1935 to 1946. In 1943, in construction of eight Arctic bases, he was Paving Engineer for the consultant firms of Messrs. Shreve, Lamb and Harmon and Messrs. Fay, Spofford and Thorndike.

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During the period 1947-1951, Mr. Benson was Bituminous Engineer and Head of the Bituminous Laboratory of the U. S. Bureau of Reclamation, in Denver, leaving this position in January, 1952, to join The Asphalt Institute. He is past President of the Association of Asphalt Paving Technologists and a Registered Professional Engineer in Kansas. His other technical affiliations include the Kansas Engineering Society and the Highway Research Board.

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